Source, transport, mine site inventory, and geological site inventory

Determine the loads and forms of mercury from an investigation of existing data and from new data collection activities.

Map locations of mercury mines and mercury prospects.

Map locations of geological sources of mercury, such as springs.

Identify urban inputs of mercury.

Categorize sources based on size, mercury loading, and clean-up potential.

Transformation and bioavailability studies

Develop and undertake a set of studies of bioavailability and methylation to understand the specific geochemical and hydrological factors that contribute to the production of biologically available forms of mercury.

Develop and undertake a set of studies to understand the specific geochemical and hydrologic factors that contribute to demethylation or detoxification of mercury in the watershed.

Identify locations in the watershed with low and high bioavailability.

Develop a general or specific model of mercury transformation and bioavailability in the watershed.

Studies to determine relationship between mercury loads and mercury bioaccumulation

Develop and undertake a study of mercury bioaccumulation. This will require sampling multiple species and trophic levels in aquatic food webs. Identify potential indicator species that show major steps in the entry or accumulation of methyl mercury in food webs. These species may serve as target indicators to follow the effects of remediation.

Develop a general or specific model of bioaccumulation for sport fish species and wildlife.

Link models of mercury transformation and bioavailability to those of bioaccumulation in order to model the relationship between observed mercury loads and observed fish contamination for as much of the watershed as possible.

Refine new data collection activities to fill gaps in models. Test relationships between observed data and models.

Remediation demonstration

Develop a variety of remediation options and projects that are based on changing mercury loading, transport, transformation, or bioavailability for different sections of the watershed.

Use valid models to test the effects and time frame for various remediation options.

Evaluate and prioritize remediation options, based on feasibility, cost, expected results, and time frame.

Select and implement a remediation project(s) with a short-term time frame for expected results.

Information management

All of the above activities will require the development of a centrally located database or the development of common standards for a database so that data from a variety of agencies can be merged for interpretation and used by all researchers and water quality managers.

A Geographic Information System (GIS) using readily available information software, such as Arcview, should be developed so that chemical and spatial information related to mercury management can be stored, retrieved, and used by researchers and water quality managers.

Public outreach

Continue and expand on stakeholder groups. Distribute information on new studies, health evaluations, and remediation efforts to local stakeholders and other interested parties.

Stage II - Expanded Remediation and Monitoring of Remediated Areas (a 3- to 5-year approach)

Remediation actions

Select and implement new remediation projects with expected results of intermediate or long-term time frames.

Evaluate demonstration remediation actions for success.

Refine or verify models for mercury load and fish tissue concentrations using monitoring data generated below.

Update prioritization of remediation options based on monitoring results.

Fish tissue monitoring for impacts on human health and wildlife

Continue monitoring at fishing sites and especially above and below sites during and after remediation. This effort will be ongoing to determine mercury levels during remediation and post-remediation activities in order to evaluate the level of success of those activities.

Reevaluate human health risks and wildlife impacts at remediated sites.

Monitoring major sources and transport of mercury

Continue monitoring sources and loads of mercury, including mercury in water and sediment. Include monitoring at sites during and after remediation, as well as at sites not yet being remediated. This monitoring is needed to evaluate the short- and long-term success of remediation actions.

Monitoring transformation, bioavailability, and bioaccumulation

At focused sites (such as source and sink areas) and at sites during and after remediation, monitor mercury transformation (e.g., methylation and de-methylation), conditions affecting transformations, and bioavailability.

Monitor the mercury content of indicator species at the same sites as above.

Information management and public outreach

Continue the development and implementation of an information management, GIS, and public outreach database and activity program.

Stage III - Long-Term Remediation and Monitoring of Remediated Areas (a 3- to 5-year approach)

Fish tissue monitoring for impacts on human health and wildlife

Continue fish tissue monitoring with the ultimate goal of lifting advisories and preventing the implementation of new ones.

Monitor loads and forms of mercury in water and sediment with the expectation that concentrations, loads, and toxic forms will decrease due to remediation efforts.

Evaluate the success of all remedial activities.

Continue to maintain the information database and public outreach activities.

Remediation actions

Select and implement new remediation projects with expected results of longer term time frames.

Evaluate intermediate-term remediation actions for success.

Refine or verify models for mercury load and fish tissue concentrations using the monitoring data generated below.

Update prioritization of remediation options based on monitoring results. Prioritize newly discovered sources.

Fish tissue monitoring for human health and wildlife impacts

Continue monitoring at fishing sites and especially above and below sites during and after remediation. This effort will be ongoing to determine mercury levels during remediation and post-remediation activities in order to evaluate the level of success of those activities.

Reevaluate human health risks and wildlife impacts at remediated sites. Update public outreach and communication efforts to reflect changes in risk and impact.

Monitoring major sources and transport of mercury

Continue monitoring sources and loads of mercury, including mercury in water and sediment. Include monitoring at sites during and after remediation, as well as at sites not yet being remediated. This monitoring is needed to evaluate the short- and long-term success of remediation actions.

Monitoring transformation, bioavailability, and bioaccumulation

At focused sites (such as source and sink areas) and at sites during and after remediation, monitor mercury transformation (e.g., methylation and de-methylation), conditions affecting transformations, and bioavailability.

Monitor mercury content of indicator species at the same sites as above.

Refine models linking mercury loading and concentrations in fish and wildlife based on ongoing monitoring data.

Information management and public outreach

Maintain the information management system, GIS, and public outreach database.

Update the public outreach activities and program.

4.5.2 Information Needed

1. Identification of sources of mercury in the Cache Creek watershed and its potential to result in methylation, bioavailability, and ultimately bioaccumulation.

Cache Creek has been identified as a major source of total mercury to the Yolo Bypass and the Bay-Delta estuary. In 1995, for example, 1,000 kg of mercury was exported from the creek. Approximately 50% of this mercury was deposited in the Cache Creek Setting Basin, but the remainder was exported to the Yolo Bypass. However, less is known about specific sources of mercury within the Cache Creek watershed or the forms of that mercury and its potential to result in methylation, bioavailability, and ultimately bioaccumulation.

Cache Creek has been identified as a major source of total mercury to the Yolo Bypass and the Bay-Delta estuary.

Studies completed by UC Davis and a proposal submitted by the USGS have addressed or will address some of the issues concerning the bioavailability and bioaccumulation, and the sources and speciation of mercury in the Cache Creek watershed. However, those studies will not identify all sources and will not address all questions regarding the bioavailability of the mercury from those sources, or characterize the extent of mercury accumulation within aquatic organisms in the affected streams and downstream areas. Therefore, a logical sequence of steps designed to obtain the necessary information on the sources and biological effects of mercury is needed to provide water quality managers with sufficient information to plan effective remediation. These steps should include (1) studies of mercury occurrence and bioaccumulation in and downstream of the Cache Creek watershed; and (2) a monitoring program that will document the current status of mercury concentrations, the effects of any remediation activities, and the trends in mercury loadings over longer periods.

An initial mercury study should include an investigation of mercury concentrations and loads along the main stem of Cache Creek, during dry weather and during stormwater runoff conditions, followed by similar studies on specific creeks identified as possible sources of that mercury. The success of this approach will necessitate completion of concurrent studies on mercury speciation and methylation, and actual measurements of mercury in aquatic organisms along these spatial gradients. New gauging stations will need to be installed, and existing gauging stations will need to be maintained in order to accurately record discharges for calculating mercury loadings from these streams. Speciation studies include the fractionation of mercury collected from environmental samples, such as water, suspended sediment, and bed sediment according to size (dissolved, colloidal, or bulk sediment) and studies to show the mineralogical residence of the mercury. The mineralogical residence may be as cinnabar (mercury sulfide [HgS]); as mercury adsorbed to oxides of iron, manganese, or aluminum; adsorbed onto organic matter, as elemental mercury; or in other solid phases. It is expected that bioavailability is different for each of these types of mercury and may be different even for different size fractions. Therefore, bioavailability studies need to be completed on the various size fractions and mineralogical types.

Data indicating the concentrations and forms of mercury in water and sediments are useful to quantify loadings and to model or predict mercury bioavailability. However, direct measurements of mercury bioaccumulations (e.g., fish or invertebrate tissue residues) are necessary to complement these models and to validate predictions of bioavailability.

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Because aquatic insects remain in limited geographic areas, data indicating their whole-body mercury residues may be used to locate and confirm sources of contamination in the watershed. These data also indicate year-to-year variations, which would make them useful for evaluating the effectiveness of future remedies undertaken in the watershed (e.g., reclamations of abandoned mercury mines).

Continued studies of mercury accumulations in fish also are needed in the Cache Creek watershed. Methyl mercury is known to biomagnify through aquatic food webs and become concentrated in fish. Recreationally sought-after species (e.g., catfish and bass) should be collected from areas heavily used by

Continued studies of mercury accumulations in fish also are needed in the Cache Creek watershed.

the public (e.g., campgrounds and parks), and their muscle tissues should be analyzed for mercury. These data can be used in human health risk assessments.

Native fish, such as California roach, Sacramento sucker, and Sacramento pikeminnow (squawfish), should be collected throughout the watershed for determination of their whole-body residues of mercury. California roach are widely distributed because they tolerate the warmer temperatures and lower summer low flows that occur in upstream, unregulated tributaries. Sacramento pikeminnow (squawfish) are less widely distributed, and their abundance in Cache Creek may be reduced because of introduced fish such as carp and bass; but they are permanent residents of many stream segments. Pikeminnow are piscivorous (fish-eating) and prey on California roach; therefore, their body burdens are useful indicators of mercury biomagnification. Sacramento suckers are not piscivorous but are widely distributed, long-lived fish. These fish tissue residue data can be applied in an ecological risk assessment that estimates consumption-related hazards to fish-eating birds or mammals inhabiting the Cache Creek watershed.

Another priority is investigating the downstream impacts of mercury transported from the Cache Creek watershed, especially impacts in the Yolo Bypass region and the Yolo Wetlands, and in areas further downstream in the Delta and Bay. A number of issues are worthy of detailed study, including further investigation of the forms of mercury and its potential to be methylated. A recent composite bottom sediment sample collected by the USGS NAWQA Program in the Yolo Bypass between Woodland and Interstate 80 showed elevated concentrations of mercury (0.31 nanogram per gram [ng/g]). That level is similar to concentrations measured in sediments collected from Cache Creek near Rumsey. Since the Yolo Bypass and Bay-Delta region are different environments with different water chemistries relative to the Cache Creek Basin, the methylation processes and rates of methylation may be vastly different. Therefore, studies on mercury methylation and bioaccumulation completed within the Cache Creek watershed may not necessarily apply to the Yolo Bypass, Delta, or Bay because of the different chemical and hydrological environment.

Another priority is investigating the downstream impacts of mercury transported from the Cache Creek watershed, especially impacts in the Yolo Bypass region and the Yolo Wetlands, and in areas further downstream in the Delta and Bay.

It has been shown, for example, that mercury methylation rates in the Florida Everglades depend on salinity gradients and the amount of sulfate in the water. Mercury transported to the Yolo Bypass includes that originating from the Cache Creek watershed and that transported from the Sacramento and Feather Rivers, including sources in the Sierra Nevada. Therefore, detailed investigations along a salinity gradient will need to be completed. These studies also should include investigations of mercury accumulation in various aquatic and terrestrial organisms along this spatial gradient, and should include an assessment of the land uses and its effects on mercury methylation, bioavailability, and bioaccumulation. The studies also should test the effects of planned or anticipated changes in land use that may affect mercury chemistry—for example, the permanent flooding of areas for wildlife habitat that may contain elevated levels of mercury in bottom sediment. One recently funded CALFED project is examining such a scenario in part of the Yolo Bypass. That study focuses on aquatic invertebrates.

In addition to mercury methylation studies, it is critical to understand what processes affect mercury demethylation or de-toxification and to measure in-situ microbial-mediated mercury methylation and methyl mercury degradation rates. Studies showing actual rates of these processes within the entire system will greatly benefit the planning of remediation activities and cost-effective management in these critical areas.

A chemical and biological monitoring program will be required to run parallel to the studies on mercury methylation and bioaccumulation. The purpose of the monitoring program will be to document trends in mercury and methyl mercury concentrations and loads, and trends in concentrations of mercury in biological tissue. This documentation will help to clearly identify beneficial results derived from remediation activities. The monitoring program will be designed to characterize loads of mercury and methyl mercury, which will require installing new gauging stations and continuing to maintain existing ones. Biological monitoring will include measuring the amount of mercury in various organisms comprising the trophic levels of the aquatic community in the selected streams or waterways. The biological monitoring also should include a component to identify sections of streams that are used for sport fishing. The species of fish typically caught and the levels of mercury in that fish will be analyzed for mercury to better document human exposure levels. The entire monitoring program should continue for such time as necessary to establish trends in the mercury occurrence and chemistry before, during, and after remediation.

A chemical and biological monitoring program will be required to run parallel to the studies on mercury methylation and bioaccumulation. The purpose of the monitoring program will be to document trends in mercury and methyl mercury concentrations and loads, and trends in concentrations of mercury in biological tissue.

A GIS database will need to be developed to store the chemical, biological, and spatial information so that current and future water quality managers can document trends in mercury concentrations in sediment, water, and tissue of aquatic organisms. The GIS system should include new and retrospective data for Cache Creek and other sources of mercury to the Delta.

Sacramento River and Tributaries

Recent monitoring activities have documented that a significant source of mercury to the Sacramento River is present somewhere between north of Red Bluff and the park at Woodson Bridge. Significant increases of the mercury load in the Sacramento River have been documented in this reach of river during stormwater runoff periods. Synoptic (with the flow) studies for that reach of river could determine the actual source of this mercury. In addition to characterizing such

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local sources of mercury to the Sacramento River, it is also critical to understand where, when, and how methylation and demethylation of mercury occur in this portion of the Delta estuary.

The USGS NAWQA Program has completed recent monitoring for methyl mercury at six locations in the Sacramento River watershed. Those sites included three locations on the main stem of the Sacramento River, at Colusa, Verona, and Freeport; and two agricultural drains, at Colusa Basin Drain near Knights Landing and at Sacramento Slough near Knights Landing. Results of that work showed that, on a yearly basis, the median concentrations of methyl mercury at those sites are statistically similar. Mercury levels approach concentrations that would be cause for concern, but larger and more significant concentrations occur following stormwater runoff. At present, little is known about the transport of methyl mercury from sites downstream of large placer-type gold mining operations, such as in the Yuba, Bear, and Cosumnes Rivers.

Dredge tailings that line several large Sacramento River tributaries should be investigated as potential sources of mercury loading. The investigation should address the Yuba, Cosumnes, and Bear Rivers. Suitable sampling sites include the Sacramento River at Bend Bridge, at Colusa, at Verona, and at Freeport; the Feather River near Nicolaus; the Yuba River near Marysville and an additional site on the Yuba River near dredge tailings; two similarly chosen sites on the Bear River; and two similarly chosen sites on the Cosumnes River. Some sampling currently is being conducted by the Sacramento Coordinated Monitoring Program and the SRWP. These monitoring efforts should be augmented and continued through the CMARP. Monthly sampling of total and filtered water samples for mercury and methyl mercury should be completed for a period of 2 years. In addition, a detailed geochemical characterization of the mercury should be completed on samples collected across a range of flow or hydrologic conditions. Some possibilities for geochemical characterization include the determination of mercury and methyl mercury in various size fractions of suspended sediment, including colloidal material; the bioavailability of that material; and the methylation or demethylation rates that may occur in changing hydrologic and chemical environments, such as the gradient between river and estuary.

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4.5.3 Existing Activities

Statewide, 33 waters were listed on the 1998 CWA Section 303(d) list due to mercury impairment. Of these, 18 were located in the CVRWQCB's jurisdiction and six in the SFBRWQCB's area. Most listings are associated with mining and resource extraction.

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The CVRWQCB regulates active and inactive mines on an individual basis under its Waste Discharge Program, the NPDES permit program, and the stormwater NPDES program. Operators of active mines, and some inactive mines with a responsible party, are required to obtain permits for any discharges in order to limit releases of inert or non-hazardous wastes.

The Sacramento Coordinated Monitoring Program has been sampling and analyzing for total and dissolved mercury since December 1992. The SRWP has been monitoring for mercury and conducting studies of fish tissue concentrations of mercury.

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The Sulphur Bank Mercury Mine, located near Clear Lake in the Cache Creek watershed, is a federal Superfund site. UC Davis researchers have been investigating mercury methylation, transformation, transport, and bioaccumulation extensively throughout this system since 1992.

EPA has conducted a Preliminary Assessment and Site Investigation of the New Idria Mine site, as a first step in considering whether to add the New Idria Mine site to the National Priorities List (NPL). Sites identified on the NPL fall under the authorities of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) for remediation.

The California Department of Conservation's Division of Mines and Geology maintains a database on abandoned mines in the state.

The Colorado Center for Environmental Management received a grant from EPA to organize stakeholders in the Cache Creek watershed in order to develop a comprehensive watershed management plan. This is called the Cache Creek Watershed Project.

The Sacramento River Mercury Control Planning Project, funded by EPA, includes a proposed implementation plan for control of mercury from both point and non-point sources in the Sacramento River watershed. The draft plan calls for several source control strategies, including reclaiming mine tailings, removing mine tailings, removing instream mercury-enriched sediments, changing the operation of reservoirs and dredging of mercury-rich sediments in major reservoirs, treating mine drainage, further regulating gold mining operations, and creating a mercury recycling program.

> The USGS has developed a method to identify deposits of mercury in hydraulic mining debris and has begun to survey mercury concentrations in that debris.

The USGS has developed a method to identify deposits of mercury in hydraulic mining debris and has begun to survey mercury concentrations in that debris. The USGS also has submitted proposals for Category 3 funding to begin studying the methylation processes in different types of habitats in the Bay-Delta, as well as the food web transfer of mercury, in order to identify the species most likely to be contaminated by mercury. The USGS will continue to monitor total mercury and methyl mercury at two Sacramento River sites during the low-intensity phase of the NAWQA Program. Those sites are the Sacramento River at Colusa and the Sacramento River at Freeport. The low-intensity phase of the NAWQA Program will continue from the federal fiscal year 1999 through 2003. After that, a new monitoring plan will be formulated for the basin. Total and methyl mercury will be monitored on a monthly basis, and mercury in river sediment and tissue of aquatic organisms will be monitored on a yearly basis.

Research at the UC Davis Department of Environmental Science and Policy addresses ongoing projects at reservoirs and creeks, including Davis Creek Reservoir, Clear Lake, the Marsh Creek watershed, streams throughout the Sierra Nevada gold mining region, and new work throughout the Delta. Researchers from UC Davis have determined that fish tissue concentrations can be predicted from lower trophic-level invertebrate concentrations. They have developed techniques to rank tributaries according to their relative bioavailable mercury levels, to determine key sources of bioavailable mercury, and to determine mass loadings of mercury from individual tributaries and entire watersheds. Research is ongoing concerning the factors influencing mercury methylation, transformations, transport, and movement into and bioconcentration through food webs.

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The CVRWQCB and the SWRCB are developing a pilot mercury recycling program based on existing hazardous waste recycling programs. The program includes a public outreach and education component, fostering a cooperative relationship with the gold mining community (both recreational and commercial), and establishing the infrastructure for collecting and transporting recovered mercury to commercial recyclers.

In December 1997, some CALFED Category 3 restoration funds were directed toward evaluating the effects of wetland restoration on methyl mercury production in the estuary. This 3-year study will quantify changes in methyl mercury production caused by restoration activities and evaluate the availability and impact of mercury on the Bay-Delta ecosystem. The results of this work will be used to direct longer-term ecosystem restoration activities in order to minimize methyl mercury production.

The SWRCB and the California Coastal Commission (CCC) are in the process of adopting statewide management measures for mining. The SWRCB formed a Technical Advisory Committee on mines; this committee issued its recommendations in an October 1994 report. The SWRCB, CCC, and RWQCB currently are preparing an implementation plan as required under the Coastal Zone Area Reauthorization Act.

In 1996, the Save San Francisco Bay Association received an EPA grant for its Seafood Consumption Information Project to conduct direct outreach to fishing communities (primarily Hispanic and Asian) on the health risks associated with eating fish caught in the Bay. Activities included (1) conducting surveys on the frequency of fish consumption and on awareness of OEHHA fish advisories, and (2) offering in-house workshops on how to prepare fish in order to avoid eating the most contaminated portions.